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2018

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citation for published version (APA)

Wesseldijk, L. W. (2018). *Risk factors for the development and outcome of childhood psychopathology*. [PhD-Thesis - Research and graduation internal, Vrije Universiteit Amsterdam].

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*Childhood psychopathology:
assessment and heritability*

PSYCHOPATHOLOGY IN 7-YEAR-OLD CHILDREN: DIFFERENCES IN MATERNAL AND PATERNAL RATINGS AND THE GENETIC EPIDEMIOLOGY



Chapter 2

Abstract

The assessment of children's psychopathology is often based on parental report. Earlier studies have suggested that rater bias can affect the estimates of genetic, shared environmental and unique environmental influences on differences between children. The availability of a large dataset of maternal as well as paternal ratings of psychopathology in 7-year old children enabled 1) the analysis of informant effects on these assessments, and 2) to obtain more reliable estimates of the genetic and non-genetic effects. DSM-oriented measures of affective, anxiety, somatic, attention-deficit/hyperactivity, oppositional-defiant, conduct, and obsessive-compulsive problems were rated for 12,310 twin pairs from the Netherlands Twin Register by mothers (N=12,085) and fathers (N=8,516). The effects of genetic and non-genetic effects were estimated on the common and rater-specific variance. For all scales, mean scores on maternal ratings exceeded paternal ratings. Parents largely agreed on the ranking of their child's problems (r .60-.75). The heritability was estimated over 55% for maternal and paternal ratings for all scales, except for conduct problems (44-46%). Unbiased shared environmental influences, i.e. on the common variance, were significant for affective (13%), oppositional (13%) and conduct problems (37%). In clinical settings, different cutoffs for (sub)clinical scores could be applied to paternal and maternal ratings of their child's psychopathology. Only for conduct problems, shared environmental and genetic influences explain an equal amount in differences between children. For the other scales, genetic factors explain the majority of the variance, especially for the common part that is free of rater bias.

Based on: Wesseldijk LW, Fedko IO, Bartels M, Nivard MG, van Beijsterveldt CE, Boomsma DI, Middeldorp CM (2016). Psychopathology in 7-year-old children: Differences in maternal and paternal ratings and the genetic epidemiology. *American Journal of Medical Genetics Part B: Neuropsychiatric Genetics*, 174, 251-260.

Introduction

Many childhood psychiatric disorders, including attention deficit hyperactivity disorder (ADHD), behavioral disorders and anxiety disorders, are already prevalent at age 7. Pooled prevalence rates across countries at this age are estimated in a meta-analysis at 3.4% for ADHD, 3.6% for oppositional defiant disorder (ODD), 2.1% for conduct disorder (CD) and 6.5% for anxiety disorders [88]. There are no pooled world-wide prevalences for obsessive-compulsive disorder (OCD), the estimated prevalence rates in children vary between 1% and 7% across countries [89,90]. In the current study, performed in a large sample of Dutch 7-year old twins, we investigated whether there are differences in paternal and maternal ratings of their child's psychopathology. Next, contributions of genetic, shared familial and unshared environmental factors on the differences between children in psychopathology as assessed by mothers and fathers were estimated.

Measures of childhood psychopathology below age 12 are often based on reports from mothers and/or fathers. The outcome of these assessments can depend on the rater. Earlier studies in 7-year-old children have found maternal ratings to be higher than paternal ratings [7,8,11,91-95]. The ranking of the children's problems has also been found to vary between fathers and mothers resulting in correlations of .60 between maternal and paternal ratings [95,96].

Several twin studies have investigated parental ratings of childhood psychopathology and estimated the influences of additive genetic (A), common environmental (C) factors shared by children growing up in the same household, and non-shared environmental (E) factors [1,4]. As monozygotic (MZ) twin pairs share almost all of their genetic material, while dizygotic (DZ) twin pairs share on average 50%, a higher MZ than DZ twin correlation indicates that A plays a role in differences between children. If the DZ twin correlation is higher than half of the MZ twin correlation, C, representing environmental influences that create resemblance among siblings, may also be of influence. The remaining part of the variance is attributed to E, representing environmental influences that create differences among siblings and measurement error. Genetic factors have been consistently reported to have an influence on differences between children in psychiatric disorders or symptoms. In addition, usually C was found to explain additional variation, except for ADHD [1,4].

Most estimates of A and C were based on studies that analyzed reports of one rater in which the assessments can partly reflect characteristics of the rater. A rater may systematically over or underestimate certain behavior in children and when

the same rater assesses behavior in multiple children, the extent to which they resemble each other thus can in part be due to rater characteristics [97]. In genetic epidemiological analyses, this bias will create an effect that resembles an effect of common environment (C) as this bias results in a higher resemblance in MZ as well as in DZ twins [6]. In studies that include reports of multiple raters, e.g., both parents for both twins, an unbiased estimate of the effect of shared environmental factors on childhood psychopathology can be obtained by estimating the effect of C on the part of the variance the parents agree upon. Previous multiple-rater studies in 7-year-old twins [6-11] showed that rater bias might account for around 10 to 30% of the phenotypic variance. These studies focused on broad measures of internalizing and externalizing measures or on anxious depression, thought problems and aggression. Such estimates are lacking for measures of childhood psychopathology that reflect symptoms associated with common psychiatric disorders as defined by the DSM-IV [98]. The effects of genetic and environmental factors on psychopathology have been shown to vary with age and so could the effects of rater bias [1,4,6,23]. It is therefore important to analyze groups of children with a narrow age range, when considering the impact of rater bias.

Here, we analyze data on childhood psychopathology in a large sample of twins whose parents participate in the Netherlands Twin Register (NTR). Data were collected close to their 7th birthday in 12,310 twin pairs of which 8,480 twin pairs (67.4%) have ratings available from both parents. We analyzed the DSM-oriented affective, anxiety, somatic, attention-deficit/hyperactivity, oppositional-defiant, conduct and obsessive-compulsive problems scales of the Child Behavior Checklist (CBCL) [99]. The CBCL was originally developed to assess behavioral and emotional problems across a series of empirically defined scales based on exploratory (EFA) and confirmatory (CFA) factor analysis [99,100]. In contrast, items defining DSM-oriented scales were selected when 14 out of 22 experienced child psychiatrists and psychologist judged the item to be highly consistent with the relevant DSM-IV diagnostic category [99,101]. A limited number of studies is available for the DSM-oriented scales. In one study in 398 Italian twin pairs [102], the heritability for five DSM scales (i.e. affective, anxiety, attention, oppositional-defiant and conduct problems) varied between 34% and 74% in twins aged 8-11 and between 53% and 82% in twins aged 12-17. Significant effects of C were found for affective (39%) and anxiety (30%) problems in children aged 8-11. A recent Chinese twin study [103] in 658 twin pairs aged 6-18 reported modest genetic influences (19-37%) and substantial influences of C (54-67%) for the affective, anxiety and somatic DSM-oriented CBCL scales. Chen et al. [103] discussed that these discrepancies in genetic

and environmental estimates across studies could be due to context differences, or to the broad age ranges and reports of one rater analyzed. For the obsessive-compulsive scale of the CBCL, analyzing maternal and paternal ratings yielded heritability estimates between 46% and 59% for boys and girls and an effect of C between 10% and 15% in 8,083 twin pairs at age 7 [9].

We investigated whether parents differ in the assessments of their children, whether parental agreement depends on the child's gender and to what extent differences between children are explained by genetic, shared and non-shared environmental factors by simultaneously analyzing maternal and paternal ratings of mono- and dizygotic twins.

Methods

Subjects

All participants were registered by their parents with the Netherlands Twin Register (NTR) shortly after birth [82,83]. When the twins were 1, 2, 3, 5, 7, 10 and 12 years old, parents received a survey from the NTR. The first twins were registered in 1987 and recruitment and data collection is ongoing. For the current study, data of 7-years-old twins from birth cohorts 1986-2005 were analyzed. The surveys were mailed to the parents close to the twin's 7th birthday and reminders were sent after 2 to 4 months resulting in a response rate of 55% [82]. The final sample contained 2,079 monozygotic male (MZm), 2,324 monozygotic female (MZf), 2,086 dizygotic male (DZm), 1,924 dizygotic female (DZf) and 3,897 dizygotic opposite-sex twin pairs (DOS). More mothers (N=12,085) than fathers (N=8,516) completed the survey. For the same-sex twin pairs, zygosity was determined by DNA polymorphisms for 1,752 pairs, and otherwise by items in the survey about physical resemblance. Zygosity determination based on items about physical resemblance and DNA polymorphisms are in agreement in more than 93% of the twin pairs [104].

Measures

Children's behavioral and emotional problems were assessed using the Child Behavior Checklist (CBCL) [99]. The CBCL is a rating scale for parents of children from 6 to 18 years old. It contains 118 specific items that are rated on a three-point scale (0 to 2; not true, somewhat true, very true). We analyzed variation among children's behavioral and emotional problems using the DSM-oriented CBCL scales that are consistent with diagnostic categories of the American Psychiatric

Association's [1994] Diagnostic and Statistical Manual, 4th Edition (DSM-IV), namely the DSM-oriented affective, anxiety, somatic, attention-deficit/hyperactivity, oppositional-defiant, conduct and obsessive compulsive problems scales. Good validity for the DSM-oriented scales of the CBCL was reported in a US sample, with 80% of referred and non-referred children classified correctly and correlations with DSM-IV diagnostic categories ranging between .43 and .80 [99]. In a sample of Dutch children, the anxiety problems scale moderately predicted the presence or absence of a clinical DSM-IV anxiety disorder diagnosis, while the affective problem scale closely predicted DSM-IV major depression [105]. In 2001, Nelson et al. [101] created the obsessive-compulsive DSM-oriented scale after CFA and Andersen, Bilenberg [106] confirmed high sensitivity and moderate specificity. Internal consistency in our sample, as reflected by Cronbach's α , was on average .63, ranging from .49 to .76, which is comparable to findings in Spanish validation studies [107,108].

Genetic epidemiological analyses and multiple rater models

Since MZ twins share (nearly) all their genetic material, while DZ twins share, on average, 50% of their segregating genes, a higher phenotypic MZ twin correlation indicates that genetic factors play a role. If the DZ twin correlation is higher than half of the MZ twin correlation, shared environmental effects also are of importance. If the MZ twin correlation is more than twice as high than the DZ twin correlation, it is inferred that non-additive genetic factors contribute to the phenotypic variance, in addition to additive genetic factors. Finally, the remaining part of the variance is attributed to non-shared environment effects and measurement error. This information can be captured in structural equation modelling, where the variance is decomposed into additive (A) and non-additive (D) genetic, shared environmental (C) and non-shared environmental (E) components. Since C and D have an opposing effect on the DZ twin correlations, their effects cannot be estimated simultaneously in the classical twin design. Based on the observed correlation pattern, an ACE or ADE model is tested. When ratings from mothers and fathers are available, it is possible to decompose the variances of the two ratings into a part the parents agree upon, the common part, and into two uncorrelated parts reflecting the disagreement, the rater-specific parts using the psychometric model (Figure 1) [97]. These common and rater-specific parts of the variance can be further decomposed in variance explained by A, C or D, and E. For the common part, information comes from the cross-twin-cross-rater-correlations, i.e., the correlations between the maternal ratings of twin 1 and the paternal ratings of twin 2. Rater bias is excluded from the common

part, but is contained in the rater-specific shared environmental influence (C_m and C_f). Therefore, C on the common part is an unbiased estimate of the effect of shared environmental factors. Furthermore, whether the rater-specific parts also reflect true behavior of the child is inferred from the significance of the genetic influences on these rater-specific parts (A_m and A_f), as it is unlikely that measurement error leads to an estimation of genetic influences [109].

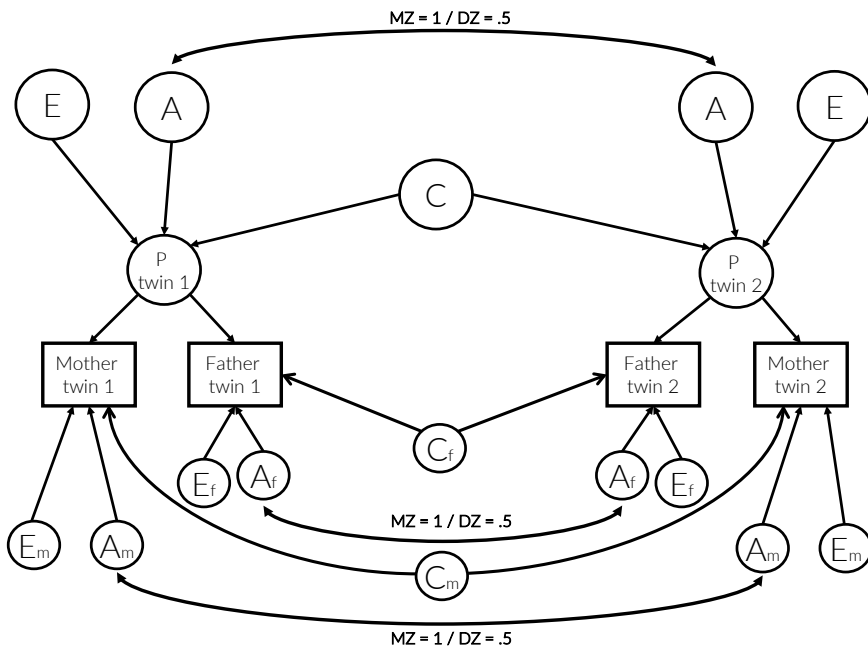


Figure 1. The psychometric model. Maternal and paternal ratings are linear functions of the latent phenotypes of the twins ($P_{\text{twin 1}}$ and $P_{\text{twin 2}}$), and rater specific variance (A_m , C_m , E_m , A_f , C_f , and E_f). When constraining A_m and A_f to zero, the model represents a restricted rater bias model with C_m and C_f representing mother's and father's bias and E_m and E_f representing residual error.

The DSM-oriented scales were highly skewed, as is usual given the relatively large number of subjects with no or little psychiatric symptoms in population based cohorts. Treating the scores as normally distributed variables would result in parameter bias and it is therefore recommended to categorize the data and fit a threshold model [110]. Dividing the data using the clinical cut-off scores consistent with the DSM-IV diagnostic categories would neglect the variation between individuals below the diagnostic threshold; previous work suggested no etiological demarcation between variation within the normal variation and at the extreme end [111]. In addition, dividing the data into 3 approximately equally sized groups instead of 2 groups yields more power [112]. Therefore, the scores were divided into three (low, middle and high) groups, and analyzed as categorical data with two thresholds [110]. In the threshold model, it is assumed that the categorical trait has an underlying continuous distribution of liability [113]. Data from boys and girls were divided into three more or less equally sized groups (percentages of children in the first two groups are shown in Table 1). As can be seen in the table, for each scale, the groups included children with identical problems scores for paternal and maternal ratings (see Table 1). Consequently, differences in thresholds for boys and girls and paternal and maternal ratings reflect differences in prevalence rates of 0, 1 or 2 scores.

The analyses were performed in OpenMx [114]. In the baseline model, we estimated the thresholds for maternal and paternal ratings in boys and girls and the polychoric correlations, reflecting the correlations on the liability distribution. In addition to the correlations between paternal and maternal ratings, twin correlations for the maternal and the paternal ratings and the cross-twin-cross rater correlations were estimated for MZm, DZm, MZf, DZf and DOS twin pairs. Sex differences in prevalence were analyzed by testing whether the thresholds could be constrained to be equal for mother and father ratings and for boys and for girls per rater. Next, we tested whether the parental agreement depended on zygosity or sex of the offspring, i.e., is parental agreement similar in MZ and DZ twins, and in boys and girls. Lastly, sex differences in the correlations were analyzed by constraining correlations between same-sex male and female twin pairs to be equal. This provides a test of quantitative sex differences in genetic architecture. To investigate qualitative sex effects, i.e. whether different genes operate in boys and girls, correlations between DZ same-sex and DOS twins were constrained to be equal [115]. The fit of these models was compared to the more general model.

Significance testing was based on the likelihood ratio test, where the negative log-likelihood (-2LL) of the constrained model is subtracted from the -2LL of the more general saturated model. The difference between the -2LL of the two models follows a χ^2 distribution with degrees of freedom (df) equal to the amount of constraints. If the difference in fit is significant, the more saturated model should be retained. If the difference in fit is not statistically significant, the constrained model should be retained to achieve the best fitting and most parsimonious model.

Based on these outcomes, the psychometric model as explained above and depicted in Figure 1 was applied to the data to estimate the influences of A, C (or D) and E on the common and rater specific parts. 95% confidence intervals were calculated to evaluate whether common and rater-specific A, C or D were significant and whether estimates were similar in mothers and fathers.

Results

Descriptives

The thresholds for boys and girls of maternal and paternal ratings in the 7-year-old Dutch twins are presented in Table 1. The mean problem scores of the untransformed data and their standard deviations are given in the Supplementary Material, Table 1. In the model as estimated in OpenMx, including thresholds and correlations, mothers scored higher than fathers as reflected by the lower thresholds for the former ($p < .001$ for all scales) (Supplementary material, Table 2). Furthermore, significant differences between boys and girls in the thresholds were observed ($p < .001$ for all scales, $p = 0.03$ for anxiety problems). Overall, girls scored higher on the affective, anxiety, somatic and OCD scales and boys on the ADHD, ODD and CD scales.

Table 1. The thresholds (Th1 and Th2) for the liability distributions of maternal (M) and paternal (F) ratings on the different DSM-oriented CBCL scales in boys and girls.

	Affective		Anxiety		Somatic		ADHD		Opp-def		Conduct		Obsessive-compulsive	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Boys														
Th1	-.09	.08	-.16	-.04	.32	.51	-.20	-.11	-.35	-.20	-.23	-.14	.07	.23
Th2	.53	.76	.50	.61	.92	1.14	.56	.47	.50	.64	.28	.38	.72	.91
Girls														
Th1	-.14	-.01	-.21	-.07	.20	.43	.15	.22	-.13	.02	.15	.20	.02	.21
Th2	.51	.71	.46	.60	.79	1.05	.89	.78	.79	.91	.72	.76	.73	.92

ADHD: Attention deficit/hyperactivity disorder.

Correlations between parents and between twins

The cross-rater correlations varied between 0.60 and 0.75 for both boys and girls within MZ and DZ twins (Table 2). The correlations were fairly similar for all scales. The parental agreement did neither depend on the zygosity of the twins ($p > 0.05$ for all scales), nor on sex except for CD where agreement was higher in boys ($p < .001$ for CD, $p > .01$ for the other scales) (Supplementary material, Table 2). Overall, parental agreement is similar in boys and girls and in MZ and DZ twins.

Furthermore, Table 2 shows the polychoric twin correlations for the maternal and paternal ratings. The MZ correlations were always higher than the DZ correlations, indicating that additive genetic factors play a role. With the exception of ADHD, the DZ twin correlations were higher than half of the MZ twin correlations which suggests influences from C. The MZ correlations for ADHD were more than twice as large as the DZ twin correlations, pointing to a role for D, besides A. The cross-twin-cross-rater correlations were higher for MZ than for DZ twins, implying that the common part of the variance is also influenced by genetic factors. There were no significant differences ($p > .01$ for all scales) between the correlations of the same-sex male and female twin pairs (quantitative sex differences), or between the DZ same-sex and DOS twins for any of the scales (qualitative sex differences) (Supplementary material, Table 2).

Genetic and environmental influences on psychopathology

Rater-specific genetic influences were significant for all DSM-oriented scales ($p < .001$) (Supplementary material, Table 2). This indicates that in addition to a common phenotype assessed by mother and father, the unique part of each parent's ratings reflects true behavior of the child.

Table 2. Polychoric cross-rater correlations for boys and girls within MZ and DZ twins, polychoric twin correlations of the maternal (M) and paternal (F) ratings, and cross-twin-cross-rater correlations for the DSM-oriented CBCL scales.

Cross-rater	Affective				Anxiety				Somatic				ADHD				Oppositional defiant				Conduct				Obsessive-compulsive			
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls				
MZ	0.66	0.67	0.66	0.64	0.68	0.66	0.75	0.72	0.74	0.69	0.67	0.61	0.62	0.62	0.60	0.60	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62				
DZ	0.66	0.64	0.64	0.65	0.68	0.67	0.74	0.73	0.70	0.67	0.63	0.68	0.63	0.64	0.60	0.60	0.64	0.64	0.60	0.60	0.60	0.60	0.60	0.60				
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F				
MZm	0.80	0.82	0.74	0.77	0.71	0.73	0.82	0.79	0.84	0.88	0.88	0.91	0.68	0.74	0.88	0.91	0.68	0.74	0.88	0.91	0.68	0.74	0.88	0.74				
DZm	0.47	0.49	0.39	0.42	0.44	0.38	0.26	0.26	0.55	0.55	0.67	0.66	0.40	0.37	0.67	0.66	0.40	0.37	0.67	0.66	0.40	0.37	0.67	0.37				
MZf	0.80	0.80	0.75	0.80	0.74	0.74	0.80	0.81	0.82	0.84	0.87	0.88	0.67	0.70	0.87	0.88	0.67	0.70	0.87	0.88	0.67	0.70	0.87	0.70				
DZf	0.48	0.49	0.40	0.48	0.48	0.40	0.23	0.25	0.54	0.57	0.68	0.70	0.32	0.33	0.68	0.70	0.32	0.33	0.68	0.70	0.32	0.33	0.68	0.33				
DOS	0.50	0.50	0.46	0.49	0.45	0.44	0.27	0.34	0.55	0.54	0.63	0.66	0.40	0.39	0.63	0.66	0.40	0.39	0.63	0.66	0.40	0.39	0.63	0.39				
Cross-twin cross-rater																												
MZm	0.54		0.49		0.47		0.62		0.65		0.60		0.44		0.44		0.44		0.44		0.44		0.44					
DZm	0.30		0.23		0.22		0.14		0.35		0.43		0.19		0.19		0.19		0.19		0.19		0.19					
MZf	0.53		0.49		0.46		0.59		0.58		0.54		0.40		0.40		0.40		0.40		0.40		0.40					
DZf	0.31		0.25		0.21		0.08		0.33		0.40		0.12		0.12		0.12		0.12		0.12		0.12					
DOS	0.31		0.27		0.25		0.17		0.33		0.41		0.20		0.20		0.20		0.20		0.20		0.20					

ADHD: Attention deficit/hyperactivity disorder.

Table 3 shows the overall heritability estimate and the overall effects of shared and non-shared environment (A, C/D and E contributions to the common plus maternal or paternal rater-specific part) on the left. The individual parameter estimates and their confidence intervals of the A, C/D and E contributions to the common and rater-specific variance are displayed in the middle. The two columns on the right give the total percentage of variance explained by the common part and the standardized parameter estimates of A, C or D and E solely on the common part of the DSM-oriented CBCL-scales. This C estimate is unbiased. As an example, for affective problems, combining genetic influences on the commonly assessed part with the genetic influence on the maternal rater-specific part results in a heritability estimate of 62% using maternal ratings (43 [Acommon] + 19 [Am] in Table 3). The commonly assessed part of affective problems explains 65% (43 [A] + 9 [C] + 13 [E]) of the total variance and the contribution of C on the commonly assessed part is 14% (9 [Ccommon] / 65 [A+C+E common]) (shown under estimates on the % common in Table 3).

ADHD yielded the highest heritability with estimates of 81% and 80% for maternal and paternal ratings. For all other scales, except CD, adding the common and rater-specific parts resulted in heritability estimates between 54% and 64% (bold in Table 3). For CD, lower heritability estimates were reported, namely 44% and 46%. For all scales, higher genetic influences were found on the commonly assessed variance (ranging between 52% and 82%) than on either the maternal or paternal ratings (ranging between 44% and 80%). The larger contribution of genetic effects to the common part of the ratings is due to lower contributions of C. Based on the 95% confidence intervals, differences in rater-specific genetic influences between parents were observed for somatic problems, ODD and OCD, with significantly higher estimates for father ratings than for mother ratings. For the remaining scales, the rater-specific genetic influences were equal between fathers and mothers, resulting in equal total heritability estimates for the parents. Furthermore, significant rater-specific C, which includes rater bias, was found for all scales (ranging between 7 and 20%), except for ADHD for which the effect of D was estimated. Rater-specific C was smaller for the affective, anxiety and OCD problems scale (8-13%) than for the somatic, ODD, and CD problems scale (10-20%). Maternal-specific C was significantly higher for somatic, ODD and OCD problems than paternal-specific C. The estimates of the proportion of the common variance explained by C was significant for affective (14%), ODD (13%) and CD problems (37%) (Table 3). Recall that this estimation of C is free of rater bias.

Table 3. The estimates of the total additive genetic (A) (depicted in bold), shared (C) or non-additive genetic (D) and non-shared environmental (E) contributions to the common plus the rater-specific part for the maternal and paternal ratings are on the left side of the table. The parameter estimates [confidence intervals] of the A, C/D and E contributions to the common and rater-specific parts are in the middle. The last two columns give the total percentage of variance explained by the common part and the standardized parameter estimates of A, C or D and E on solely the common part of the DSM-oriented CBCL-scales. The reliable shared environmental effect is underlined.

	Maternal ratings	Paternal ratings	Common part	Rater-specific mother's part	Rater-specific father's part	Total % common	Estimates on the % common
Affective	A	62	43 [40-49]	19 [14-24]	19 [14-23]	65	66
	C	17	9 [4-11]	8 [4-13]	9 [7-14]		<u>14</u>
	E	20	13 [11-13]	7 [5-9]	6 [4-8]		20
Anxiety	A	63	46 [41-51]	17 [11-22]	18 [12-23]	64	72
	C	11	2 [0-7]	9 [4-12]	12 [7-17]		<u>3</u>
	E	26	16 [15-17]	10 [8-11]	6 [4-8]		25
Somatic	A	55	47 [45-49]	8 [2-11]	17 [15-20]	68	69
	C	18	0 [0-0]	18 [18-20]	10 [7-10]		<u>0</u>
	E	28	21 [19-21]	7 [4-7]	6 [5-8]		31
ADHD	A	23	2 [0-12]	21 [19-23]	20 [19-22]	73	3
	D	58	58 [48-60]	0 [0-0]	0 [0-0]		79
	E	19	13 [13-15]	6 [5-7]	6 [4-8]		18
Oppositional defiant	A	56	50 [49-55]	6 [4-6]	11 [10-14]	69	72
	C	27	9 [6-11]	18 [17-21]	15 [13-17]		<u>13</u>
	E	17	10 [9-11]	7 [6-8]	4 [3-5]		15

Conduct	A	44	46	34 [29-39]	10 [6-14]	12 [7-17]	65	52
	C	44	43	24 [21-28]	20 [15-24]	19 [15-23]		<u>37</u>
	E	12	10	7 [6-9]	5 [4-7]	3 [2-5]		11
Obsessive-compulsive	A	54	63	41 [39-44]	13 [6-18]	22 [15-29]	62	66
	C	13	7	0 [0-0]	13 [10-17]	7 [2-13]		<u>0</u>
	E	33	29	21 [19-23]	12 [10-15]	8 [5-11]		34

ADHD: Attention deficit/hyperactivity disorder.

Discussion

We provided an overview of maternal and paternal symptom scores and the genetic, shared, and unshared environmental contributions to individual variation in DSM-oriented problem scales measured at age 7: affective, anxiety, somatic, attention-deficit/hyperactivity (ADHD), oppositional-defiant (ODD), conduct (CD), and obsessive-compulsive (OCD) problems. Maternal ratings exceeded paternal ratings of child psychopathology for all scales, regardless of the child's sex. Furthermore, parents agreed to a large extent (correlations between 0.60 and 0.75) on the ranking of the problems in their children. Differences in the unique rater parts were explained by significant genetic influences as well as by rater bias. Hence, parents assess unique aspects of their child's behavior, but are also somewhat biased in their assessment. Regarding the contributions of genetic and environmental effects, the following points are noteworthy: the estimates of A, C or D and E were comparable in boys and girls and largely comparable across raters, heritability estimates were generally around 60%. Estimates were comparable over scales, except for ADHD which was also influenced by D, and for CD which yielded lower heritability estimates and higher estimates for the influence of C. On the common part unbiased shared environmental influences were significant for affective problems (13%), ODD (13%) and CD (37%). This signifies that for the remaining scales, it is possible that the common environmental effects as found in our and previous studies on the rater specific parts of the parental ratings or on reports of one rater are due to rater bias.

In this study, the correlations between parental measures are quite large, this indicates that parents generally agree on the ranking of their child. However, scores on maternal ratings were, on average, higher than scores on paternal ratings for all problem scales, i.e., mothers report on average more behavioral and emotional problems of their children than fathers did. This is in agreement with prior studies in 7-year-old children using different scales of the CBCL [7,8,11,92,93]. Since the cut-offs for subclinical or clinical scores as defined in the manual are the same for maternal and paternal ratings, children rated by their mother will more often pass the threshold than children rated by their father due to this difference between raters. This is especially important in situations where these scores are used to screen children for psychiatric symptoms, for example, to decide which children may benefit from an intervention, either prevention or treatment or to decide which children are eligible for inclusion in research studies. Consequently, it could be considered to apply different cut-offs for (sub)clinical scores for reports from mothers and fathers. Furthermore, our findings confirm that relying on a single parent for rating probably

results in biased estimates of the influences of C [6-11]. We report reliable influences of C, free of rater bias, for affective problems, ODD and CD in 7-year olds only. Our C estimates were smaller than reported by Spatola et al. [102] in Italian twins aged 8-11 and Chen et al. [103] in Chinese twins aged 6-18, which can be explained by the fact that we used a smaller age range and multiple informants. Neither did we find a significant effect of C for OCD on the common part like van Grootheest et al. [9], who also used the common perception shared by both parents, not confounded by rater bias, to estimate a unbiased C of 10% on OCD in 7-year-old twins. However, our study used a larger sample size and categorized the data. Derks et al. [110] showed that the use of categorized data leads to unbiased estimates of genetic and environmental effects in L-shaped distributed data.

Furthermore, we found a high contribution of C (37%) on CD, which is discrepant with the two earlier studies that estimated C on the DSM-oriented CD scale [102,116]. Besides rater bias, there are two other biases that can confound C; namely imitation among twins and assortative mating. When twins imitate one another more than other siblings do, this can result in higher estimates of C, as this behavior increases the correlations of both monozygotic and dizygotic twins, but affects the dizygotic variances to a greater extent [117,118]. This can be detected by analyzing whether there are differences in the MZ and DZ thresholds [117]. This was not the case in our sample for CD ($p=0.78$). Assortative mating, the tendency for people to mate with those who are more similar to themselves, can lead to an increase in genetic similarity in dizygotic twins, but not in monozygotic twins (as they already share 100% of their genes), which can also confound C. Spousal resemblance has been reported for scores on the DSM-oriented scales in a population-based sample, but not to a greater extent for antisocial problems than for other psychopathologies [119] and therefore cannot explain the high contribution of C solely on CD. Future research on the role of C on CD in young children is therefore recommended. Genetically informative designs, such as children-of-twins or adoption studies are most suitable since these designs offer possibilities to account for genotype-environment correlations [120,121].

This study has several strengths and weaknesses. The distribution of the different CBCL DSM-oriented scales were highly skewed, and we therefore analyzed the data using a threshold model, resulting in lower statistical power compared to an analysis of continuous data [110]. However, the parameter estimates in a threshold model are more accurate than in an analysis of continuous data [122]. While scores on the CBCL DSM-oriented scales are associated with the presence or absence of

DSM diagnoses [99], they are not the same. Therefore, the heritability estimates apply only to the questionnaire scales. The major strength of this study is that we have fully explored informant effects and the influence of genetic and environmental factors on the rarely studied DSM-oriented scales of the CBCL in a large 7-year-old twin sample.

To conclude, this study shows that, besides the substantial genetic influence on the common and rater-specific parts for all scales, there appears to be a reliable effect of C only for affective, ODD and CD problems and not for anxiety, somatic and OCD problems. Additionally, fathers and mothers assess their child's psychopathology differently and this should be evaluated when using parental reports.

Supplement to chapter 2

Table 1. Mean and standard deviations of the maternal (M) and paternal (F) ratings on the different DSM-oriented CBCL scales in boys and girls.

	Affective		Anxiety		Somatic		ADHD		Oppositional defiant		Conduct		Obsessive-compulsive	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Boys														
Means	1.20	0.93	1.23	1.01	0.71	0.51	2.50	2.21	2.57	2.25	1.76	1.49	0.98	0.76
SD	1.67	1.42	1.58	1.36	1.22	0.99	2.31	2.11	2.06	1.95	2.38	2.09	1.51	1.27
Girls														
Means	1.25	0.97	1.28	1.04	0.84	0.58	1.82	1.63	2.08	1.84	0.99	0.89	0.99	0.74
SD	1.69	1.43	1.56	1.34	1.31	1.04	2.01	1.86	1.86	1.76	1.62	1.50	1.48	1.23

ADHD: Attention deficit/hyperactivity disorder.

Table 2. Test statistics of the bivariate model fitting analyzing the rater and gender effects, the psychometric model and the rater bias model. The saturated model included all correlations reported in Table 2. The more restricted models were compared to this model. In model 6 the correlations between monozygotic males (MZm) and females (MZf) and the dizygotic males (DZm) and females (DZf) were constrained to be equal (quantitative sex differences), and in model 7 it was tested whether the dizygotic same-sex (DZ) and opposite-sex (DOS) correlations could be constrained to equal (qualitative sex differences).

		-2LL	df	Compared to	X ²	P-value
Affective	1 Saturated	75488.05	40959	-	-	-
	2 Equal thresholds father mother	75839.84	40963	1	351.80 (4)	<.001
	3 Equal thresholds boys and girls	75511.67	40963	1	23.61 (4)	<.001
	4 Parental agreement across zyg	75489.64	40961	1	1.60 (2)	0.45
	5 Parental agreement across sex	75489.77	40962	4	0.12 (1)	0.73
	6 MZm=Mzf & DZm = DZf	75493.62	40968	5	3.85 (6)	0.70
	7 DZ=DOS	75494.64	40971	6	1.02 (3)	0.80
	89 Psychometric model Am and Af constrained to 0	75494.64	40971	-	-	-
Anxiety	1 Saturated	75628.6	40973	8	133.97 (2)	<.001
	2 Equal thresholds father mother	77968.84	41049	-	-	-
	3 Equal thresholds boys and girls	78159.90	41053	1	191 (4)	<.001
	4 Parental agreement across zyg	77979.24	41053	1	10.41 (4)	0.03
	5 Parental agreement across sex	77969.82	41051	1	0.98 (2)	0.61
	6 MZm=Mzf & DZm = DZf	77969.90	41052	4	0.08 (1)	0.78
	7 DZ=DOS	77974.40	41058	5	4.50 (6)	0.61
	89 Psychometric model Am and Af constrained to 0	77982.29	41061	6	7.90 (3)	0.05
		77982.29	41061	-	-	-
		78091.7	41063	8	109.41 (2)	<.001

34	Somatic	1	Saturated	65198.48	40387	-	-	<.001
		2	Equal thresholds father mother	65645.15	40391	1	446.67 (4)	<.001
		3	Equal thresholds boys and girls	65260.85	40391	1	62.37 (4)	<.001
		4	Parental agreement across zyg	65198.61	40389	1	0.13 (2)	0.94
		5	Parental agreement across sex	65199.47	40390	4	0.87 (1)	0.35
		6	MZm=Mzf & DZm = DZf	65206.23	40396	5	6.67 (6)	0.34
		7	DZ=DOS	65210.61	40399	6	4.38 (3)	0.22
		89	Psychometric model Am and Af constrained to 0	65211.35 65266.22	40399 40401	- 8	- 54.87 (2)	- <.001
	ADHD	1	Saturated	73282.32	41031	-	-	-
		2	Equal thresholds father mother	73521.55	41035	1	239.23 (4)	<.001
		3	Equal thresholds boys and girls	73812.43	41035	1	530.11 (4)	<.001
		4	Parental agreement across zyg	73282.66	41033	1	0.34 (2)	0.84
		5	Parental agreement across sex	73284.21	41034	4	1.54 (1)	0.21
		6	MZm=Mzf & DZm = DZf	73294.54	41040	5	10.33 (6)	0.11
		7	DZ=DOS	73300.78	41043	6	6.24 (3)	0.10
		89	Psychometric model Am and Af constrained to 0	73336.9 73470.2	41043 41045	- 8	- 133.30 (2)	- <.001
	Oppositional defiant	1	Saturated	74038.30	41027	-	-	-
		2	Equal thresholds father mother	74281.41	41031	1	243.11 (4)	<.001
		3	Equal thresholds boys and girls	74394.69	41031	1	356.39 (4)	<.001
		4	Parental agreement across zyg	74044.16	41029	1	5.86 (2)	0.05
		5	Parental agreement across sex	74051.05	41030	4	6.89 (1)	0.01
		6	MZm=Mzf & DZm = DZf	74060.66	41036	5	9.61 (6)	0.14
		7	DZ=DOS	74061.13	41039	6	0.48 (3)	0.92
		89	Psychometric model Am and Af constrained to 0	74061.13 74104.59	41039 41041	- 8	- 43.46 (2)	- <.001

Conduct	1	Saturated	70398.71	40957	-	-	-
	2	Equal thresholds father mother	70463.16	40961	1	64.44 (4)	<.001
	3	Equal thresholds boys and girls	71249.75	40961	1	851.03 (4)	<.001
	4	Parental agreement across zyg	70399.92	40959	1	1.20 (2)	0.55
	5	Parental agreement across sex	70413.14	40960	4	13.23 (1)	<.001
	6	MZm=Mzf & DZm = DZf	70423.13	40966	5	9.98 (6)	0.13
	7	DZ=DOS	70433.41	40969	6	10.28 (3)	0.02
	89	Psychometric model Am and Af constrained to 0	70433.62	40969	-	-	-
			70536.03	40971	8	102.42 (2)	<.001
Obsessive- compulsive	1	Saturated	73790.27	40660	-	-	-
	2	Equal thresholds father mother	74115.01	40664	1	324.74 (4)	<.001
	3	Equal thresholds boys and girls	73807.62	40664	1	17.34 (4)	<.001
	4	Parental agreement across zyg	73791.37	40662	1	1.11 (2)	0.57
	5	Parental agreement across sex	73794.66	40663	4	3.28 (1)	0.07
	6	MZm=Mzf & DZm = DZf	73802.06	40669	5	7.41 (6)	0.29
	7	DZ=DOS	73805.56	40672	6	3.50 (3)	0.32
	89	Psychometric model Am and Af constrained to 0	73811.38	40672	-	-	-
			73893.64	40674	8	82.26 (2)	<.001

ADHD: Attention deficit/hyperactivity disorder.